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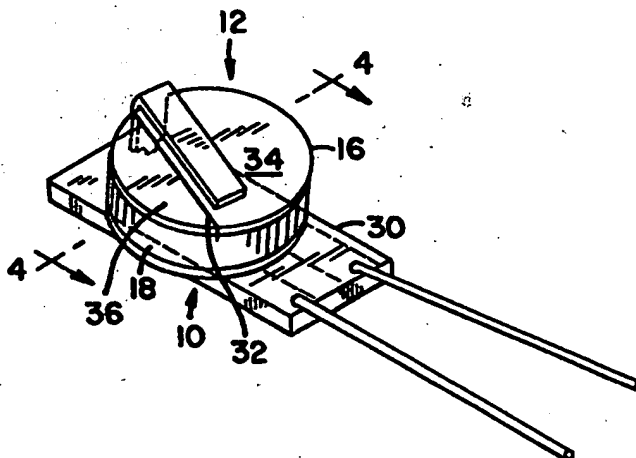
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(71) Applicant: LITTELFUSE, INC. [US/US]; 800 East Northwest Highway, Des Plaines, IL 60016 (US).		Published Without international search report and to be republished upon receipt of that report.	
(72) Inventors: STOFFEL, James, P.; 451 Cedar Court South, Buffalo Grove, IL 60089 (US). WARD, Mike, A.; 732 Independence Drive, Palatine, IL 60074 (US).			
(74) Agents: GARGANO, Jeffrey, R. et al.; Wallenstein & Wagner, Ltd., 53rd floor, 311 S. Wacker Drive, Chicago, IL 60606 (US).			

(54) Title: IMPROVED DUAL ELEMENT CIRCUIT PROTECTION DEVICE

(57) Abstract

The invention is a combination electrical fuse, said combination comprising, in series, a positive temperature coefficient (PTC) disc-shaped component (12) and a fusible link. The PTC disc-shaped component (12) comprises a central region (18), including PTC material and outer, circular electrodes on opposite sides of the disc-shaped component. The PTC material is preferably ceramic barium titanate, and the fusible link is preferably a thin metal wire. The fusible link and PTC material are enclosed within an insulating material, which is preferably made of a thermoplastic.



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**IMPROVED DUAL ELEMENT
CIRCUIT PROTECTION DEVICE**

DESCRIPTION

Technical Field

5 The invention relates to a dual element electrical device comprising (1) a positive temperature coefficient (PTC) element, and (2) a fuse. These dual elements are connected in series to create a fuse or circuit protection device having improved characteristics. This circuit protection device is especially suitable for certain applications in the telecommunications industry.

Background Of The Invention

Telephone switching stations are subject to damage in the event of sudden increases in voltages in their electrical circuits. The current induced by these voltage spikes can be damaging to telephone equipment. These sudden voltage increases may result from lightning strikes on telephone lines, or from the crossing of power lines with telephone lines.

Telephone switching stations are protected by primary and secondary protectors. Primary protectors are located outside the switching station where the telephone cable enters the building which houses the switching station. Dissipative circuitry in the primary protectors provides threshold protection against voltage spikes caused by lightning strikes and the crossing of power lines with telephone lines, and dissipates the resulting excess energy to ground.

In some instances, not all of the energy will be dissipated by these primary protectors. In these instances, the secondary protectors provide the switching station with the necessary additional protection. Each main telephone line entering the switching station is insulated, and this insulation encloses thousands of wires. Upon entry of these main telephone lines into the switching station, these thousands of wires are separated into pairs of wires. Each of these pairs of wires is secured to a so-called line card. A digital line card converts the signal created by the phone call from analog to digital. That signal is then processed, and the phone call from the placing party is connected digitally, through the switching station, to the receiving party.

The secondary protection on the line card is typically provided by a pair of so-called "tip and ring" devices for each phone line. These two devices are on analog side of the line card, and produce the dissipation effects on the signal before its analog to digital conversion.

Shown in photographs to be submitted with the Information Disclosure Statement is a device manufactured

by Raychem of California, and sold by Raychem as Catalog No. TR600-ISO. This device was reviewed by the inventors of the present application. Although this device includes a PTC material in its circuit, it does not include a PTC material in series with a fuse.

Generally relevant patents include U.S. Patent Nos. 5,239,163, 5,229,739, 5,208,723, 4,903,295, 4,808,965, 4,788,519, 4,780,598. 4,654,510 and 3,708,720.

Another relevant patent is U.S. Patent No. 4,967,176. This patent is entitled "Assemblies Of PTC Circuit Protection Devices" and claims a device comprising at least three circuit protection elements connected in series. Each of those elements comprises a laminar PTC element which is sandwiched between two laminar metal electrodes. This patent also claims an electrical circuit breaking system which comprises a circuit breaker and a device assembly which is connected in series with the circuit breaker and which comprises at least five PTC elements.

The devices that are presently used for such secondary protection in so-called tip and ring circuits are not believed to be able to provide protection against catastrophic failure at 600 volts and currents of up to 60 amps.

Summary Of The Invention

The invention is a combination electrical fuse. The combination comprises, in series, a positive temperature coefficient (PTC) element and a fusible link. Preferably, the PTC element is a disc-shaped component. The disc-shaped component may be formed from a central region including a PTC material, and from outer, circular electrodes on opposite sides of that disc-shaped component.

One example of a suitable PTC material is ceramic barium titanate. The fusible link may comprise a thin metal wire.

The combination electrical fuse of the invention may have both its fusible link and its PTC material enclosed within an insulating cover. A suitable insulating material is a thermoplastic material.

The electrical fuse of this invention may include a very fast-acting fusible link. In this context, a very fast-acting fusible link is a device which will remain closed or conductive, at 100 percent of the ampere rating of that device, for at least four hours. Such a device will also remain closed or conductive, at 200 percent of the ampere rating, for no more than one second; and at 300 percent of the ampere rating, for no more than 0.1 seconds.

An objective of the present invention is a dual element circuit protection device which provides circuit protection up to 600 volts and 60 amps of current, protects the PTC element against catastrophic failure, and yet is able to reset under certain current overload conditions. The inventors know of no other device which satisfies these requirements.

Brief Description Of The Drawings

FIG. 1 is a perspective view of a preferred embodiment of a device in accordance with the invention.

5 FIG. 2 is a perspective view of the device of FIG. 1, but with the disc-shaped PTC element exploded away from the rest of the device.

10 FIG. 3 is a view of the reverse side of the printed circuit (PC) board that includes the fusible link of the device of FIG. 1, showing in addition contacts and the regions of copper tracing on the PC board.

FIG. 4 is a cross-sectional view of the device of FIG. 1, and taken along lines 4-4 of FIG. 1.

15 FIG. 5 is a perspective view of the embodiment of FIG. 1, but enclosed within a snap-on, hollow, thermoplastic cover which maintains the disc-shaped component in contact with the PC board that includes the fusible link.

FIG. 6 is a cross-sectional view of the device of FIG. 5, and taken along lines 6-6 of FIG. 5.

20 FIG. 7 is an exploded perspective view of a second embodiment of the invention, showing a matched pair of the elements of FIG. 1 within one enclosure.

FIG. 8 is an assembled, perspective view of the embodiment of FIG. 7.

Detailed Description Of The Preferred Embodiment

The present invention is a combination electric resettable fuse device 10 which comprises, in series, (1) a PTC element 12, and (2) a fusible link 14. These two elements are shown, respectively, in the perspective view of the resettable fuse device 10 of FIG. 1 and in FIG. 3. For the purposes of this invention, the meaning of "resettable" is a device which will (1) open a circuit upon defined overload conditions, and (2) close the circuit when those overload conditions are removed from the circuit. This resettability is accomplished by the PTC element 12, as will be explained later.

The device 10 shown in this particular embodiment comprises a PC board 30 in which the fusible link 14 has been etched. In the preferred embodiment, this fusible link 14 will be made of copper, and have a trace width of between approximately 5 and 7 mils, i.e., 0.005 to 0.007 inches. Under the intended conditions of use for this device 10, it will be seen that this fusible link 14 acts as a short circuit element, rather than like a more conventional fuse element.

It will be understood by those skilled in the art, however, that the fusible link that is an essential part of the invention need not be etched into a PC board 30. Rather, the PC board 30 may be eliminated, and the fusible link may be obtained from a conventional fuse which is placed in series with the PTC element 12 of the device 10. This conventional fuse could have an amperage rating and opening characteristics similar to those of the present fusible link 14. Such a conventional fuse may include one of the 263000 series of Littelfuse PICO® II 250 volt, very fast-acting fuses, which are manufactured by Littelfuse, Inc., the assignee of the present invention. The fusible link 14 of this PICO® II fuse comprises a thin metal wire.

Very fast-acting is a term of art in the fuse trade whose meaning is understood by those skilled in the art. Very fast-acting fuses include, but are not limited to, those which (1) remain closed or conductive, at 100

percent of the ampere rating, for at least four hours; (2) will remain closed or conductive, at 200 percent of the ampere rating, for no more than one second; and (3) will remain closed or conductive, at 300 percent of the ampere rating, for no more than 0.1 seconds.

As may best be seen in FIGS. 1, 2 and 4, the PTC element 12 is a generally disc-shaped component or pellet comprising a central region or core 18. That central region or core 18 is made of a PTC material. In the preferred embodiment, this PTC element 12 is approximately 9.5 millimeters in diameter and approximately 2.5 millimeters thick. Along its thickness, this PTC element 12 includes seven layers, best shown in FIG. 2. The middle layer or core 18 referred to above is the thickest of these seven. As indicated above, this middle layer or core 18 is comprised of a PTC core material, preferably ceramic barium titanate.

A suitable ceramic barium titanate is available from Ceramite Corp. of Grafton, Wisconsin. The pellet- or disc-shaped PTC element 12 of the present invention, including its flat circular electrodes, is available from Ceramite as Part No. 307 C 1210. Another pellet-shaped PTC element 12 suitable for the invention, and available as a standard part from Ceramite, is Part No. 307 C 1130. This pellet has a resistance of 15-ohms, plus or minus 20 percent. Although both pellets have ceramic barium titanate cores 18, PTC materials other than ceramic barium titanate may also be suitable for the device of the invention.

As may be seen in FIGS. 4 and 6, the remaining six layers form outer, circular top 20 and bottom 22 electrodes on opposite sides of the PTC element 12. Particularly, each of these electrodes 20 and 22 includes three layers. The first or inner layer 24 of each electrode 20 and 22 is immediately adjacent the middle, barium titanate core layer 18, and is made of aluminum. It is applied using thick film methods.

The second intermediate layer 26 is made of a non-solderable silver, using thick film screening. The third outermost layer 28 comprises the outward facing portion of each electrode 20 and 22, and is the layer that is farthest removed from the barium titanate layer 18. This third layer 28 is made of a solderable silver, for both improved corrosion resistance and for facilitating contact with circuit contact points in the device 10.

It will be understood by those skilled in the art, however, that any number of metals may be used for these electrodes 20 and 22. These metals may include nickel, chromium and many other conductive metals, as is well-known to those skilled in the art.

In operation, this device 10 is essentially a dual element, resettable electric fuse. In normal operation, the circuits protected by the present devices operate at a steady state condition of between 100 and 200 milliamps. Under relatively low overload conditions, i.e., with a voltage of 600 volts and a current of above about 200 milliamps and as high as 7 to 10 amps, the resistance of the PTC element 12 will increase suddenly and substantially.

The overload current range of from about 200 milliamps to about 7 amps is the so-called resettable region of the present device 10. In operation, upon an increase in circuit current to between 200 milliamps and 7 amps, the resistance of the PTC element 12 will increase markedly. In fact, this increase in resistance will be to an extent that will reduce the flow of current through this PTC element 12 to a very low level that will not harm the protected circuit. In one typical device, for example, at between 200 milliamps and 7 to 10 amps, the resistance of this disc-shaped PTC element 12 will increase from 100 to at least one megaohm at 600 volts.

In summary, the present device 10 has a resettable region. In this resettable region, the resistance of the PTC element 12 increases rapidly, reducing current flow through the protected circuit. The

present device 10 has the capability of resetting when the current in the protected circuit drops from a level above 200 milliamps to a level below about 200 milliamps.

5 There is a possibility that the PTC material could fail, i.e., its resistance may not rise upon an increase in the current through the protected circuit. Under these conditions, there is a potential for the current through this circuit, and through the PTC element 12, to rise to a level of between 10 and 40 amperes. At
10 that level, current surging through the PTC material could cause that material to fail catastrophically, exploding or disintegrating.

To guard against this possibility, when the current rises to between about 10 and 40 amperes, the
15 fusible link 14 (FIG. 3) is designed to open rapidly, preventing this high current from passing through the circuit for an extended period of time. When this fusible link 14 opens, current flow through the device 10
and the protected circuit is completely interrupted.

20 The PC board 30, including the fusible link 14, will have a relatively negligible resistance of approximately 0.1 ohm. Unlike the PTC element, the fusible link 14 which opens under these extreme conditions does not reset. Thus, when the fusible link
25 14 opens, the device 10 cannot be reused and must be replaced.

It will be understood by those skilled in the art that the devices 10 in accordance with the invention can be tailored to meet the differing needs of each
30 particular user. In particular, the point at which the resistance of the PTC element 12 increases suddenly can be varied by changing the size, material, blend and other characteristics of the PTC element.

One of the objectives achieved by the present
35 invention is an electric resettable fuse device 10 which is suitable for protection of currents of up to 60 amps in a 600 volt circuit. The present invention accomplishes this by a combination of elements 12 and 14 which, individually, cannot protect circuits under 60

amp, 600 volt conditions. Under conditions up to 60 amps at 600 volts, the present combination devices will not be subject to catastrophic failure, such as explosions or ruptures. This has been demonstrated in tests performed on devices in accordance with the invention.

As may best be seen in FIGS. 1 and 2, a chord 32 splits the electrode into two segments of unequal size. The first segment 34 is the larger of the two, while the second segment 36 is substantially smaller. As may best be seen in FIG. 4, the chord 32 is cut through all three layers 24, 26 and 28 of the top electrode 20, so that the cut is deep enough to reach top of the core 18 of PTC material. In this way, the first segment 34 is completely physically separated from the second segment 36.

The splitting of the top electrode 20 into segments 34 and 36 by means of the chord 32 effectively reduces the resistance of the PTC element 12 of the device 10. This reduction in resistance is effected by using only one segment, preferably segment 34, in the electrical circuit through this device. The smaller of the segments, second segment 36, does not come into contact with any of the circuit components within the device 10, and is effectively isolated by chord 32 from that circuit.

A review of FIGS. 2 and 3 shows the path taken by current through this device 10, and the electrical contacts conductively securing the PTC element 12 to that device 10. In particular, current enters the PC board 30 through an inlet lead 38. The PC board 30 is pre-printed with copper tracing, as shown in the shaded portions of FIGS. 2 and 3. Current enters a first region 40 of copper tracing on the PC board 30 through an inlet lead 38. From this first region 40, the current passes on to the second region of copper tracing 42 through the printed fusible link 14. Current then passes through a bracket 44, which may be bent, leaving space between its end and the PC board 30 for insertion of the disc-shaped PTC element 12. After the current moves into the disc-

shaped PTC element 12, it passes through a contact 46 and thereafter enters the third region 48 of copper tracing. From this third region 48, the current leaves the device 10 through an outlet lead 50.

5 Other methods for matching pairs of PTC elements may be employed, including resistance sorting from zero power resistance measurements; and trimming by mechanical means, as with an abrasive device.

10 To ensure that the disc-shaped PTC element 12 makes good electrical contact with the bracket 44 and the contact 46, a two-piece, hollow insulating cover 52 is provided. This cover 52 may be made of any insulating material, but is preferably made of a thermoplastic material. The cover 52 snaps onto and surrounds the
15 device, except for the inlet 38 and outlet leads 50. The cover 52 need not be, and preferably is not, airtight.

 Ribs 54 are provided on the inside portion of the upper half of the cover 52. These ribs 54 bear down upon the copper bracket 44, and press it into tight
20 engagement with the first segment 34 of the top electrode 20. In this way, the disc-shaped PTC element 12 is securely held between the bracket 44 and the contact 46. The ribs 54 are also designed to ensure that the bracket will not come into contact with the second segment 36 of
25 the top electrode 20.

 Although the above construction is preferred in terms of cost and performance, it will be understood that the thermoplastic cover 52 could be eliminated. If this cover 52 were eliminated, the first segment 34 of top
30 electrode 20 could instead be soldered to the bracket 44, and the bottom electrode 22 could be soldered onto the contact 46 formed on the PC board 30.

 The provision of a hollow, non-airtight cover 52 is important for functional reasons. Air preferably
35 surrounds the PTC element 12 because of the inevitable oxidation which occurs. Particularly, when the PTC element 12 becomes hot, oxidation occurs in the barium titanate core 18 of PTC material, in the top 20 and bottom 22 electrodes of the PTC element 12, and on the

other components of the device, including on the copper traces of the PC board 30. By definition, when oxidation occurs, there must be a source of the oxygen for use in that reaction. When the PTC element 12 is enclosed in a hollow cover 52 or housing, the space between the device 10 and the housing 52 contains air, which acts as the source of oxygen.

If there were no air surrounding the device 10 and the PTC element 12, oxidation would still occur upon an increase in the temperature of the device 10. Without air surrounding the device 10, however, the source of the oxygen for oxidation would be the ceramic PTC element 12 itself and, particularly, the middle layer or core 18 of barium titanate material. The leaching of this oxygen from the PTC element 12 would undesirably reduce the PTC characteristics of the barium titanate.

FIGS. 7 and 8 depict a common, non-airtight enclosure for a pair of the devices of FIG. 1. The thin enclosure is made of two pieces which snap together. The outward-facing portions of the enclosure are of a smooth, generally rectangular configuration. The inward-facing portions of the enclosure are formed to closely match the shape and size of the two devices contained by that enclosure. In this manner, the devices will be securely retained within the enclosure.

When assembling the apparatus of FIGS. 7 and 8, one should ensure that this pair of devices within this common enclosure will have extremely closely matched electrical characteristics. This is critical when such devices are used in a tip and ring circuit. If the pair of devices were to be used in a tip and ring circuit and were not enclosed in a common enclosure, then the user would need to take precautions to ensure that the pair of devices used in each tip and ring circuit had these closely matched characteristics. If the device pair used in a tip and ring circuit did not have closely matched electrical characteristics, then excessive noise would be encountered on the phone line served by that circuit.

It will also be understood that a single device may be enclosed in a smooth enclosure like that shown in FIGS. 7 and 8, rather than the tight, form-fitting enclosure of FIG. 5.

5 It is to be understood that various modifications within the scope of this invention can be made by one of ordinary skill in the art without departing from the spirit of the invention. The invention should be defined by the scope of the claims as
10 broadly as the prior art will permit. Those of skill in the art will understand that various changes may be made, and equivalents may be substituted for elements of the claims, without departing from the broader aspects of the invention.

CLAIMS

What I claim is:

1. A combination electrical fuse, said combination comprising, in series:

- a. a positive temperature coefficient element; and
- b. a fusible link.

2. The combination electrical fuse of Claim 1, wherein said positive temperature coefficient element comprises a disc-shaped component.

3. The combination electrical fuse of Claim 2, wherein said disc-shaped component comprises a central region including positive temperature coefficient material and outer, circular electrodes on opposite sides of said disc-shaped component.

4. The combination electrical fuse of Claim 1, wherein said positive temperature coefficient material is barium titanate.

5. The combination electrical fuse of Claim 1, wherein said fusible link comprises a thin metal wire.

6. The combination electrical fuse of Claim 1, wherein said fusible link and said positive coefficient are enclosed within an insulating cover.

7. The combination electrical fuse of Claim 6, wherein said insulating cover is of a thermoplastic material.

8. The combination electrical fuse of Claim 1, wherein said fusible link is a very fast-acting fuse.

9. A combination electrical fuse, said combination comprising, in series:

- 5 a. a positive temperature coefficient, disc-shaped component comprising a central region including positive temperature coefficient material and outer, circular electrodes on opposite sides of said disc-shaped component; and
- b. a fusible link.

10. The combination electrical fuse of Claim 9, wherein said positive temperature coefficient material is barium titanate.

11. The combination electrical fuse of Claim 9, wherein said fusible link comprises a thin metal wire.

12. The combination electrical fuse of Claim 9, wherein said fusible link and said positive temperature coefficient material are enclosed within an insulating cover.

13. The combination electrical fuse of Claim 12, wherein said insulating cover is made of a thermoplastic material.

5 14. A method of changing the resistance of a positive temperature coefficient device, said positive temperature coefficient device having at least a top electrode and a core of a positive temperature coefficient material below said top electrode, said method comprising cutting a chord through said top electrode until said chord reaches said core of positive temperature coefficient material, thereby dividing said top electrode into a first segment, and a second segment

10 that is completely, physically separated from said first segment.

15. The method of Claim 14, wherein said chord is placed in a position whereby the first segment is of a different size than said second segment.

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FIG. 1

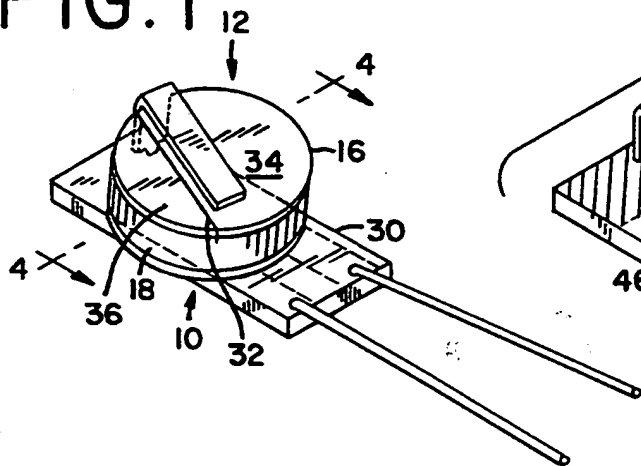


FIG. 2

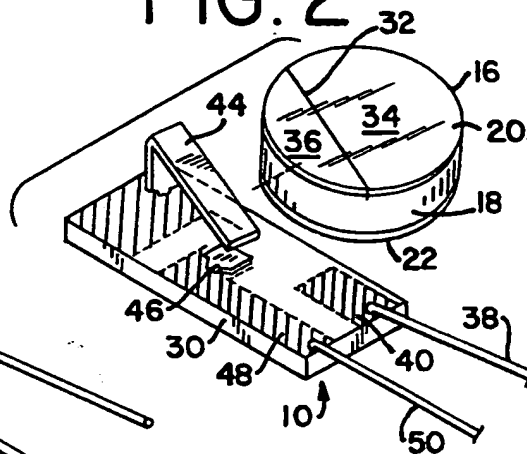


FIG. 3

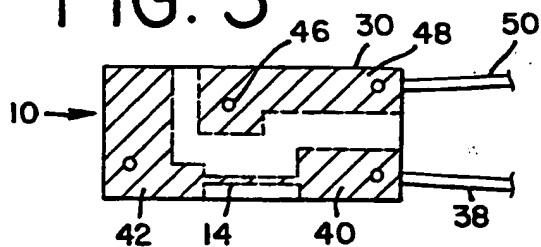


FIG. 4

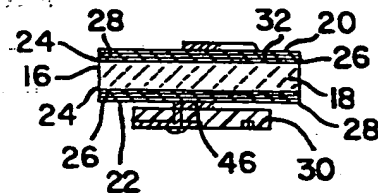


FIG. 5

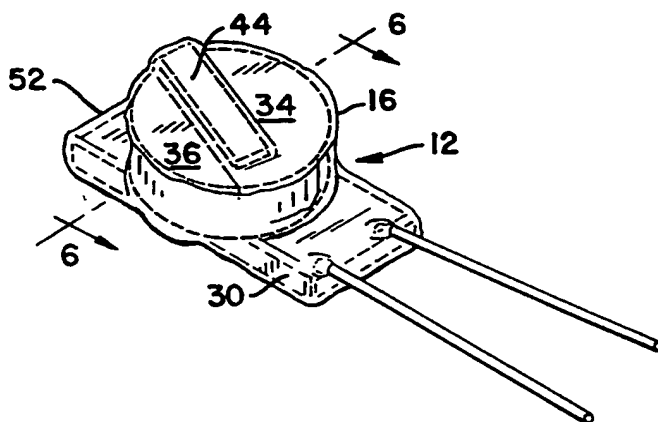
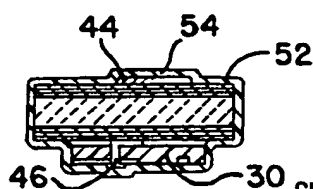


FIG. 6



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FIG. 7

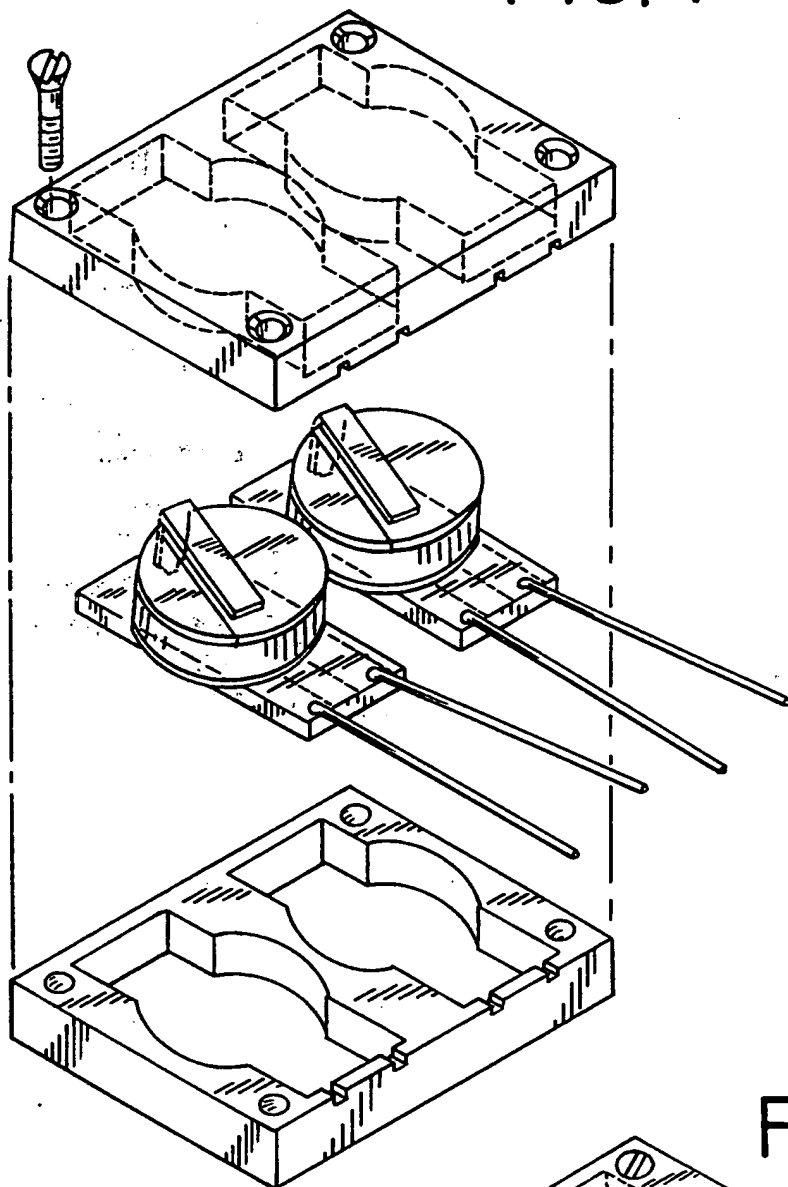
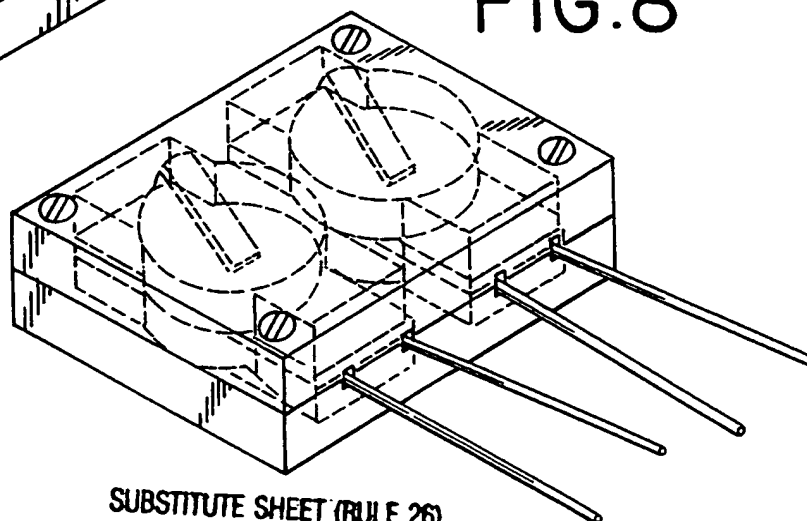


FIG. 8



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